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24. (Amended) A process for etching away a fixed thickness of silicon oxide in an integrated circuit structure on a semiconductor substrate in an etching apparatus which comprises:

a) exposing an oxide surface of an integrated circuit structure on a semiconductor substrate to a remote plasma consisting essentially of a remote nitrogen plasma generated by a first rf power source maintained at a power level of from about 250 watts to about 500 watts; and

b) maintaining on said semiconductor substrate an rf bias generated by a second rf power source maintained at a power level of from about 10 watts to about 50 watts during said exposure of said oxide surface to said remote nitrogen plasma;

whereby a fixed thickness of silicon oxide will be removed from said oxide surface, with the oxide thickness removed dependent upon the power level on said semiconductor substrate of said rf bias from said second rf power source.

REMARKS

Claims 4, 7, and 9-24 remain in the application. Claims 4, 7, 10-11, 13-14, 19-20, and 23-24 have been amended. Claims 5-6, and 8 have been cancelled in this amendment.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "**VERSION WITH MARKINGS TO SHOW CHANGES MADE**".

I. SUMMARY OF THE JANUARY 7TH, 2003 OFFICE ACTION

Section 103 Rejection

Claims 4-24 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Puntambekar et al. U.S. Patent 5,714,037 in view of Barnes et al. U.S. Patent 5,284,549.

II. THE REFERENCES

A. The Puntambekar et al. Reference

Puntambekar et al. U.S. Patent 5,714,037 teaches the roughening of a silicon oxide surface of a silicon oxide film in a nitrogen plasma in an RIE plasma etcher operating at a high DC bias of 600 volts or greater.

B. The Barnes et al. Reference

Barnes et al. U.S. Patent 5,284,549 discloses a CHF_3-based RIE etching process which is disclosed using a nitrogen additive to provide high selectivity of SIO_2 or PSG to AL_2O_3, thereby permitting use of an etch stop layer. The process uses a pressure in the range of about 200-1,000 mTorr, and an appropriate RF bias power, selected based on the size of the substrate being etched. The substrate mounting pedestal is preferably maintained at a temperature of about 0°C. Nitrogen can be added to the plasma-forming CHF_3 gas from a nitrogen-containing molecule, or as N_2. He gas can be added to the gas mixture to enhance the RIE lag-reducing effect of the nitrogen.

III. THE INVENTION

The invention comprises a process for etching oxide wherein a reproducibly accurate and uniform amount of silicon oxide can be removed from a surface of an oxide layer previously formed over a semiconductor substrate. The oxide is exposed, in an etch chamber, to a plasma consisting essentially of a nitrogen plasma generated by a first rf power source maintained at a

power level ranging from about 250 watts to about 1000 watts. At the same time, an rf bias, generated by a second rf power supply maintained at a power level of from above zero up to a power level just below a level at which sputtering of said substrate materials would commence, is applied to the substrate support on which the substrate is supported in the etch chamber. The thickness of the oxide removed in a given period of time may be changed by changing the amount of rf bias applied to the substrate by the second rf power source through the substrate support.

IV. DISCUSSION

Claims 4-24 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Puntambekar et al. U.S. Patent 5,714,037 in view of newly cited Barnes et al. U.S. Patent 5,284,549.

A. The Puntambekar et al. Patent

The Puntambekar et al. patent was cited and relied upon, at least as a secondary reference, in three previous Office Actions. In the last Office Action, as well as the current Office Action mailed 01/07/03, the USPTO states that Puntambekar et al. teach a two step nitrogen plasma process wherein the first step is an initialization step necessary to strike the plasma. The Office Actions then state that, during step 2, Puntambekar et al. operate their plasma etcher at a ***high DC bias of 950 volts***.

The Office Actions then call attention to the recitation of an rf power of 400 watts for both steps in Table 1 of Puntambekar et al. From this recitation in the reference, the USPTO draws the conclusion that this reads on Applicants' limitation of maintaining an rf ***bias*** on the semiconductor substrate.

Applicants, in their previous response, called attention to three flaws in this reasoning:

1) Puntambekar et al. do not state (or infer) that their recited rf power is a ***bias*** power or voltage (applied to their semiconductor substrate).

2) Puntambekar et al. do not state or imply that their recited rf power is coupled to their semiconductor substrate (or the substrate support).

3) The Puntambekar et al. recited minimum rf power of 600 watts (for nitride etching) is 6 times Applicants' maximum rf ***bias*** power of 100 watts (recited in the first paragraph of Applicants' specification on page 3).

To the above comments previously made, Applicants add the following:

1) Puntambekar et al. do not state (or infer) that their recited rf power is a ***bias*** power or voltage applied to their semiconductor substrate. Rather, one skilled in the art would probably recognize that the reason for the continuous application of rf power during both steps of the Puntambekar et al. process is to maintain the plasma ignited in the first step, rather than to furnish an rf bias power.

2) Puntambekar et al. do not state or imply that their recited rf power is coupled to their semiconductor substrate (or the substrate support). One skilled in the art would not expect Puntambekar et al. to connect their source of rf power to the semiconductor substrate to furnish an rf source of bias power since a high DC voltage is already being utilized.

3) The Puntambekar et al. recited minimum rf power of 600 watts (for nitride etching) is 6 times Applicants' maximum rf ***bias*** power of 100 watts (recited in the first paragraph of Applicants' specification on page 3). One skilled in the art:

a) would not readily recognize that the recited 600 watts of power was to be applied to the substrate support as a bias power (rather than to maintain the plasma);

b) would not recognize the need to change the bias power source from a DC source to an rf power source; and

c) would not recognize the need to change the bias power from a high value to a low value. On the other hand, one skilled in the art might

recognize that the use of such a high power rf source as a bias power applied to the substrate might well serve to either roughen the oxide surface (as Puntambekar et al. intended it to do) or even possibly destroy the oxide layer.

Puntambekar et al. does not teach a method whereby a fixed thickness of silicon oxide can be removed from an oxide surface by a nitrogen plasma powered by a first rf source with the amount of oxide thickness removed dependent upon the power level of a low power rf bias powered by a second rf power source applied to the substrate support in the etching chamber.

B. The Barnes et al. Patent

Barnes et al. U.S. Patent 5,284,549 has now been cited against Applicants' claims in combination with the above discussed Puntambekar et al. patent. The Office Action, after at least acknowledging that "...Puntambekar et al. does not teach a method for maintaining an rf bias on the semiconductor substrate during the exposure of the oxide surface to a remote nitrogen plasma", the Rejection then goes on to say that Barnes discloses a reactive ion etching method for etching silicon oxide (SiO_2) over an etch stop material on a workpiece in an etching chamber. Applicants have also noted these differences between the Barnes et al. process and Applicants' claimed process, as well as other differences.

(1) The Barnes et al. Etch Stop Layer

First of all, how would an etch stop layer be utilized in the accurate removal of ***some*** oxide from an oxide layer as in Applicants' process? One skilled in the art would immediately recognize that the Barnes et al. etch stop layer is normally used when one desires to remove ***all*** of the material (such as an oxide layer) overlying the etch stop layer. Even if one rationalized that the oxide etching could be stopped as soon as the underlying etch stop layer became exposed, on would still have an undesired opening or hole in the oxide layer being thinned. Suppose that the claimed process was being used to accurately thin an oxide layer to provide a gate oxide of thin, yet accurate thickness. A layer of oxide having randomly occurring holes

therein would be of little value where it is desired to construct a thin gate oxide layer for an MOS structure on a silicon substrate.

(2) The Need for Nitrogen by Barnes in the Absence of an Etch Stop Layer

If the etch stop layer of Barnes et al. is not used in a process, then the reason put forth by Barnes et al. for adding nitrogen to the CHF_3 gas used to form the Barnes et al. plasma is also lost, since the reason give by Barnes et al. for the use of nitrogen as an additive to their CHF_3 etching gas is to enhance the selectivity of their CHF_3 etchant gas for the etch stop layer. In column 3, at lines 7-22, Barnes et al. explains this as follows:

> "The present inventors have discovered that high selectivity of etched SiO_2 or PSG, to an etch stop such as Al_2O_3, can be achieved by inhibiting the etching of the etch stop material, which in turn can be achieved by reducing the gas radical and ion vibrational temperature of a RIE etching plasma. The addition of a nitrogen containing molecule (such a molecule defined herein as including the pure nitrogen molecule N_2), to a CHF_3 RIE gas plasma has been discovered to be beneficial in this effect, in that nitrogen has vibrational states close to those of the fluorocarbons, and thus functions as a plasma vibrational energy sink. Moreover, it is theorized that, when such nitrogen is added to the CHF_3 gas plasma, a thin layer of AlN forms to further inhibit the etching of the AL_2O_3 etch stop layer."

Thus, one following the Barnes et al. teachings would either include the etch stop layer taught by Barnes et al. (resulting in an entirely different process than the process taught and claimed by Applicants) or eliminate the etch stop layer, in which case one skilled in the art would also eliminate the addition of nitrogen to the CHF_3 gas since the need for the nitrogen in the plasma (to enhance the selectivity to the etch stop layer material) would be eliminated by omission of the etch stop layer.

(3) The Barnes et al. Mixture of Gases in Their Plasma

The Office Action recites that the Barnes et al. RIE etching plasma contains nitrogen and CHF_3, with the nitrogen added to enhance the selectivity of the CHF_3 plasma to the materials comprising the etch stop layer. Applicants' rf plasma consists essentially of a nitrogen plasma formed from either nitrogen or a nitrogen-containing substance. Applicants' use of nitrogen gas in the formation of their plasma is not merely as a supplement to a main ingredient (such as the

Barnes et al. fluorocarbon gas) to enhance the performance of that other ingredient of their plasma. Rather Applicants' plasma consists essentially of a nitrogen plasma.

(4) The Barnes et al. High Rf Bias Power

The Office Action states that the Barnes et al. rf bias power ranges from 500 watts to 700 watts. Applicants' rf bias power, in its broadest aspects, ranges from above zero to up to a power level just below a level at which sputtering of said substrate materials would commence; and typically Applicants power level ranges from about 10 watts up to about 100 watts. This is considerably lower that the 500 watts to 700 watts rf power range of the Barnes et al. reference.

(5) The Absence of a Second RF Power Source in Barnes et al.

Attention must be directed to the recitation, both in Applicants' specification and their claims, of the use of two different rf power sources by Applicants, one maintained at a very low rf power level to provide an rf bias low power source for accurate control of the amount of oxide material etched away (the thickness of the oxide removed); while the second (and more powerful) rf power source is used to ignite and maintain the nitrogen etching plasma, a task which one skilled in the art would recognize as being difficult, if not impossible, to achieve using only a single low rf power source. In contrast, however, it will be noted that Barnes et al. only refers to a single rf power supply. See, for example, Table A in the Barnes et al. patent, where only the wattage of the rf bias power is listed.

In summary:

1) Barnes et al. utilize an etch stop layer in their etching process. - Applicants do not.

2) Barnes et al. have no need for nitrogen gas in their plasma if the etch stop layer is omitted. - Applicants' etchant is their nitrogen plasma.

3) Barnes et al. form a plasma from a mixture of CHF_3 and nitrogen, with the nitrogen added to enhance the selectivity of the CHF_3 plasma etchant to the etch stop layer. - Applicants use essentially only nitrogen to form their oxide-removing nitrogen plasma.

4) Barnes et al. uses a single high power rf bias source. - Applicant use two rf power sources, a low power rf bias source to control the amount of oxide being removed, and a much higher power rf source to ignite and maintain their oxide-removing nitrogen plasma.

5) Barnes et al. uses an rf power source having a power level ranging from 500 watts to 700 watts.

(6) Barnes et al. use their process for backend processing such as processing to form vias or metal lines. - Applicants' process, which uses a low rf power bias, can be used for far more delicate front end processing such as the formation of thin gate oxides of accurate thickness for MOS devices. This difference will be appreciated by those skilled in the art when comparing the respective utilities of the processes.

With respect to the differences between Applicants' claimed invention and the process of Barnes et at., it must be noted that all of the Barnes et al. teachings must be taken into account when considering whether or not Applicants' claimed invention would be obvious from Barnes et al.

The CAFC has held that a reference may not be considered in less than its entirety and that disclosures in a reference that diverge from or teach away from the invention, may not be disregarded. In the case of W.L. Gore and Associates v. Garlock, Inc., 220 USPQ 303, the CAFC stated, at page 311:

> "In its consideration of the prior art, the district court erred...in considering the references in less than their entireties, i.e., in disregarding disclosures in the references that diverge from and teach away from the invention at hand."

In the case of Bausch & Lomb v. Barnes-Hind/Hydrocurve, 230 USPQ 416, the CAFC reaffirmed its position on using only selected portions of a reference by quoting, on page 419, the following excerpt from an earlier CCPA case (In re Weslau, 147 USPQ 391):

> "It is impermissible within the framework of section 103 to pick and choose from any one reference only so much of it as will support a given position to the exclusion of other parts necessary to a full appreciation of what such reference fairly suggests to one skilled in the art."

When all of the teachings of Barnes et al., as enumerated above, are taken into account, Applicants' claimed invention is not suggested by the cited combination of art. Applicants' claims should now be allowable over the cited references.

If the Examiner in charge of this case feels that there are any remaining unresolved issues in this case, the Examiner is urged to call the undersigned attorney at the below listed telephone number which is in the Pacific Coast Time Zone.

Respectfully Submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the Claims:

Claims 4, 7, 10-11, 13-14, 19-20, and 23-24 have been amended as follows:

4. (Amended) A process for etching away a fixed thickness of silicon oxide in an integrated circuit structure on a semiconductor substrate in an etching apparatus which comprises:

a) exposing an oxide surface of an integrated circuit structure on a semiconductor substrate to a ~~nitrogen~~ plasma consisting essentially of a nitrogen plasma generated by a first rf power source maintained at a power level of from about 250 watts to about 1000 watts; and

b) maintaining on said semiconductor substrate, an rf bias from a second rf power source maintained at a power level of from above zero up to a power level just below a level at which sputtering of said substrate materials would commence ~~on said semiconductor substrate~~ during said exposure of said oxide surface to said nitrogen plasma;

whereby a fixed thickness of silicon oxide will be removed from said oxide surface, with the oxide thickness removed dependent upon the power level of said rf bias on said semiconductor substrate.

7. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 4 wherein said nitrogen plasma consists essentially of ~~comprises~~ a remote rf plasma generated by said first rf power source at a distance from said oxide surface sufficiently far enough that recombination of at least some of the electrons with the ionic nitrogen species occurs so that the flux of ionic nitrogen species will be reduced from the initial flux created at the nitrogen plasma origin,

10. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 4 wherein said oxide surface exposed to said nitrogen plasma comprises an oxide layer previously formed on said integrated circuit structure to form a gate oxide thereon.

11. (Amended) A process for etching away a fixed thickness of silicon oxide in an integrated circuit structure on a semiconductor substrate mounted on a substrate support in an etching chamber of an etching apparatus which comprises:

a) exposing an oxide surface of an integrated circuit structure on a semiconductor substrate to a ~~nitrogen~~ plasma consisting essentially of nitrogen formed by ~~flowing a gas containing nitrogen into said etching apparatus, and then~~ igniting ~~a~~ said nitrogen plasma in said etching apparatus, using a first rf power source maintained at an rf power level of from about 250 watts up to about 1000 watts; and

b) maintaining, on said substrate support, during said exposure of said oxide surface to said nitrogen plasma, an rf bias from a second rf power source maintained at a power level ranging from above zero up to a power level just below a level at which sputtering of said substrate materials would commence;

whereby a fixed thickness of silicon oxide will be removed from said oxide surface, with the oxide thickness removed dependent upon said power level of said rf bias on said substrate support.

13. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 11 wherein said nitrogen plasma is maintained using said first rf power source at an rf ~~a~~ power level of from about 250 watts to about 500 watts.

14. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 11 wherein said nitrogen plasma generated by said first rf power source consists essentially of ~~comprises~~ a remote nitrogen plasma.

19. (Amended) A process for etching away a fixed thickness of silicon oxide in an integrated circuit structure on a semiconductor substrate which comprises:

a) placing said semiconductor substrate on a substrate support in an etching chamber of an etching apparatus, said chamber maintained at a pressure of from about 1 millitorr to about 500 millitorr;

b) exposing an oxide surface of an integrated circuit structure on a semiconductor substrate to a ~~nitrogen~~ plasma consisting essentially of nitrogen maintained at a power level of from about 250 watts to about 500 watts by a first rf power source and formed by flowing nitrogen ~~a~~ gas ~~containing nitrogen~~ into said etching apparatus, and then igniting a plasma in said etching apparatus; and

c) maintaining, on said substrate support, during said exposure of said oxide surface to said nitrogen plasma, an rf bias maintained at an rf ~~a~~ power level ranging from above zero up to about 100 watts by a second rf power source;

whereby a fixed thickness of silicon oxide will be removed from said oxide surface, with the oxide thickness removed dependent upon said rf power level of said rf bias on said semiconductor substrate.

20. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 19 wherein said power level of said second rf power source generating said rf bias on said substrate ranges from above zero up to about 50 watts.

23. (Amended) The process for etching away a fixed thickness of silicon oxide of claim 19 wherein said nitrogen plasma generated by said first rf power source consists essentially of ~~comprises~~ a remote nitrogen plasma.

24. (Amended) A process for etching away a fixed thickness of silicon oxide in an integrated circuit structure on a semiconductor substrate in an etching apparatus which comprises:

a) exposing an oxide surface of an integrated circuit structure on a semiconductor substrate to a remote ~~nitrogen~~ plasma consisting essentially of a remote nitrogen plasma generated by a first rf power source maintained at a power level of from about 250 watts to about 500 watts; and

b) maintaining ~~an rf bias~~ on said semiconductor substrate an rf bias generated by a second rf power source maintained at a power level of from about 10 watts to about 50 watts ~~comprises~~ during said exposure of said oxide surface to said remote nitrogen plasma;

whereby a fixed thickness of silicon oxide will be removed from said oxide surface, with the oxide thickness removed dependent upon the power level ~~of said rf bias~~ on said semiconductor substrate of said rf bias from said second rf power source.